

transformed by the Fresnel rhomb in two normal and linear vibrations. It depends upon the position of the Nicol which of the components of the doublet is the more quenched.

The initial position of the Nicol determines the angle through which it is to be turned in order to reverse the relative intensities of the two components. Only widened lines and no doublets, and correspondingly only a shift and no extinguishing of components by turning the Nicol, will be observed, either from want of uniformity of the field or from want of homogeneity of the light.

The phenomena observed by Prof. Hale in the double lines and the widened lines of the sun-spot spectrum, and exemplified in the photographs under review, are identical in character with those observed in the laboratory under the specified conditions with somewhat broad lines or in a rather non-uniform field. The behaviour of a spectral line emitted in these circumstances by iron vapour between the poles of an electromagnet cannot be distinguished from the radiation of iron vapour immersed in the interior of a Hale (electronic or corpuscular) solar vortex at a distance of 149 million kilometres.

So far as we know, only a strong magnetic field can resolve a single line into a doublet, having components circularly polarised in opposite directions. Are we not compelled, then, to admit that where these unique and characteristic phenomena are present a magnetic field must be their cause? The evidence is of the same nature (but still more convincing by the unique character of the polarisations) as that for motion in the line of sight from the Doppler displacement of spectral lines in the case of moving stars or molecules.

The absence of any shift of the red telluric lines by the rotation of the Nicol, or of measurable displacements of the cyanogen flutings, as reported by Prof. Hale, considerably strengthens the argument and excludes instrumental and other errors.

A quantitative comparison of the magnetic separations of the iron lines as observed in the laboratory and in the sun will be necessary to complete the argument and to make it, if full correspondence exists, almost insuperable. A small probability, of course, must be left open that under the conditions existing in the solar furnace, dissociation processes or something of the kind (Lockyer) occur, so as to alter the whole vibrating system of the atoms and therefore also the relative separations of the different lines.

Being in the country I unfortunately cannot supply now the magnetic separations of the region of Prof. Hale's photograph.

The iron spectrum in the magnetic field has been examined by Becquerel and Deslandres, Reese, Kent, and Hartmann (Thesis, Halle, 1907), but the lines investigated are not far enough in the red.

Recently Miss van Meurs made in the Amsterdam laboratory a rather extensive study of the radiation of iron in the magnetic field, which will be published shortly; her observations in the red are still unfinished.

In order to obtain an idea of the order of magnitude of the magnetic force within the Hale solar vortex, we can only compare the largest separation of an iron line observed by Prof. Hale, viz. 0.22 \AA.U. , with that of one of the larger separations of iron lines measured in the laboratory. The separation of $\lambda 4144.05$ is 0.67 \AA.U. in a field of 29,740 Gauss. This gives for the magnetic force nearly 10,000, which may be reduced to, say, 6000 Gauss, if Dr. Hale's line presents such exceptionally high separation as some zinc lines.

If we might identify the Hale vortex with a solenoid with axis parallel to that of the vortex, and having

one layer of one winding per cm., a current of 5000 amp. would be necessary for generating the 6000 Gauss field.

This current at first sight seems rather large. The actual case is approached more nearly by substituting for the one winding per cm. a gaseous conducting circular disc, one cm. thick, and of suitable radius, though all calculations here are merely tentative and extremely rough. Let the radius of this disc be chosen equal to that of the earth, viz. $6.4 \times 10^8 \text{ cm.}$ (representing a solar vortex of, according to Hale's photographs of the solar vortices, extremely moderate dimensions), then the current of 5000 amp. in the disc is to be distributed over an area of $64 \times 10^8 \text{ cm}^2$, giving 0.8×10^{-5} amp. per cm^2 .

The cathode rays issuing from the spot of lime (say one square millimetre area) in a Wehnelt tube carry something like 10^{-5} amp. (I quote from memory). Hence the solar vortex would not be too crowded with electrons even if the magnetic force to be accounted for were much higher.

In the last paragraph of my very first paper (1897) concerning radiation in the magnetic field, I wrote:—"Further inquiry must also decide as to how far the strong magnetic forces existing, according to some, at the surface of the sun may change its spectrum." Since I always entertained the expectation, sometimes amounting almost to conviction, that some day a cosmical application of the magnetic separation of the spectral lines would be discovered by astronomers. This might suggest that I am too favourably disposed towards any evidence in such a direction.

I trust, however, that I have not been too sanguine while writing this review of Prof. Hale's splendid discovery. Its importance for general and solar physics must be very great, and not less for the theories of meteorology and terrestrial magnetism, affording, as it does, a *vera causa* for the perturbations of the electric and magnetic equilibrium of our earth and its atmosphere.

P. ZEEMAN.

THE LIQUEFYING OF HELIUM.

ON July 10 Prof. H. Kamerlingh Onnes, of Leyden University, and his assistants had the satisfaction of seeing a considerable volume of liquid helium remain for some hours. This conquest over the last and most refractory gas was made known within a day or two, but few details were given until the appearance of the official publication, from which this note¹ is taken.

Prof. Onnes points out that the first step necessary was the determination of isothermals of helium, and in particular of those at temperatures obtainable only with liquid hydrogen. From these the *a* and *b* of van der Waals's theory can be obtained, and the Boyle point, i.e. the temperature at which the minimum of *p**v* occurs with very small densities, be found. This point also occurs at one-half the absolute temperature of the Joule-Thomson inversion point at low densities. With these data he was able to apply a theorem developed in 1896 from an earlier and more general theorem of 1881 during the endeavour to liquefy hydrogen statically. The theorem shows that the Boyle point of helium lies somewhat above the lowest temperatures obtainable with hydrogen, and hence that a regenerative process, as applied by Linde and Hampson to air and by Dewar to hydrogen, could be effective with helium.

Ever since 1883, when Prof. Onnes commenced his

¹ From the Special August Supplement to the Dutch Proceedings of the Royal Academy of Amsterdam. The note has been approved by Prof. Onnes.

work at Leyden, there has been continuous effort to reach the nadir of temperature. It has taken some years to get the necessary data for helium together. In 1905 much help was obtained from the Commercial Intelligence Office at Amsterdam under the direction of Mr. O. Kamerlingh Onnes, who obtained a sufficiency of the monazite sand, used for the preparation of helium, at a cheap rate. The helium is obtained from this by heat, and is then most carefully purified. The first isotherm determinations on helium were made in 1907. It was owing to Olszewski's and Dewar's failures that various methods, such as the helium motor with vacuum glasses as cylinder and piston, were considered, but these were abandoned, owing to the results of the isotherm determinations, which pointed to a critical temperature of about 5° to 6° K. This result was in better agreement with Dewar's estimate of 8° K. obtained from experiments of absorption by charcoal than with Olszewski's of below 2° K.

However, the conclusion from the isotherms was not quite decisive, as those at the lowest temperature indicated a lower critical temperature than those at higher temperatures, and this appeared to throw some doubt upon the strict applicability of the law of corresponding states to helium. At all events, just before the experiment was undertaken it was shown that the Boyle point, though below the boiling point of hydrogen, was somewhat above 15° K., which is obtainable with liquid hydrogen under reduced pressure.

The time had hence arrived to reap the fruit of the many years of work devoted to building up the cryogenic laboratory for the use of prolonged accurate measurements in liquid gases, with all the circulations so arranged that the gases remain pure. This is particularly important in the hydrogen cycle, where 4 litres of liquid can be dealt with per hour and a supply can be obtained in a state of great purity and stored for use.

In the arrangement of the experiment constant use was made of the theory of van der Waals. The apparatus was made as small as possible, but there was a practical limit which was fixed by its necessary relation to the other apparatus in use. To compress the helium the special mercury pump was used which was completed in 1888, and was used to give baths of static oxygen in 1894. It compresses to 100 atmospheres, which, with the critical pressure below 5 atmospheres for helium, is a high reduced pressure. This pump circulates 1400 litres per hour, which is sufficient with the dimensions of the apparatus taken, and has a capacity with connections of about 200 litres. For this experiment it was not possible to run the helium and hydrogen cycles at the same time, so that sufficient liquid hydrogen had to be made before the experiment on helium was commenced. However, now that the main difficulties are overcome, it will be possible to work the two cycles simultaneously.

In directing attention to Sir J. Dewar's work for this and similar researches Prof. Onnes points out especially the use he has made of the selective absorption of charcoal for gases in the purification of gases under pressure, and to the advantage of silvered vacuum glasses.

Such glasses are used at every stage of the work. For example, the liquid hydrogen is collected in an unsilvered glass placed in liquid air contained in a silvered glass with a strip of clear glass left to enable the interior to be seen. The liquid hydrogen is transferred by pressure through a fine tube into the experimental apparatus.

A detailed description is given in the paper of this

apparatus, which is, however, simple enough in principle. The regenerator spiral, through which the compressed helium is expanded, is contained in the upper part of a vacuum glass also containing lower down the upper bulb of a helium thermometer. The helium glass is contained in a second which is filled with liquid hydrogen and connected to the hydrogen circulation. This glass in turn is contained in another filled with liquid air, and this finally in one containing alcohol. All these glasses are unsilvered, so that a clear view is obtained of the central glass and its contents.

The day before the successful experiment, July 9, was devoted to the preparation of 75 litres of liquid air, and at 5.45 a.m. on July 10 the work was commenced to obtain the necessary liquid hydrogen. By 1.30 p.m. 20 litres were standing in the special vacuum glasses. Meanwhile the helium and hydrogen circulations were pumped free of air and washed through with their respective gases, and a start was made to cool the liquid-air glass. At 2.30 hydrogen cooled by liquid air was taken through the hydrogen glass, and by 3 p.m. the temperature was down to -180° C. At 4.20 the helium circulation was started, liquid hydrogen was introduced into its glass, and the pressure lowered until at 5.20 p.m. it reached 6 cm., at which it was kept. Between 5.30 and 6.30 the pressure of helium in the spiral was gradually raised to 100 atmospheres. At 6.35, when the pressure was allowed to fall rapidly to 40 atmospheres, the helium thermometer indicated a temperature below that of the liquid hydrogen; nearly 6° K. was read once. At this time the last reserve of liquid hydrogen was connected, and no liquid helium had been seen. A quicker expansion was allowed, and the temperature fell and constantly returned to the same temperature of less than 5° K. It was as though the thermometer stood in liquid.

Somewhat later, at about 7.30, the surface was seen at the top of the vacuum glass. The liquid having been found under ordinary pressure there was no doubt that the critical pressure was more than 1 atmosphere. The surface was illuminated from below, and had the appearance of a liquid near the critical state in a Cagniard de la Tour tube, cutting the walls like knife-edges, though in this case the diameter was 5 cm. There was also a marked contrast between the helium and the hydrogen in the next outer tube. Some of the evaporated helium was now collected and used for a density determination giving 2.01. At 8.30 the pressure on the helium was reduced, and 2.3 cm. was measured. The pumps, however, can give 2 mm., and it is quite possible that as little as 7 mm. was reached, but no solid could be seen. At 9.40 only a few c.c. of liquid helium remained. Thus liquid helium, starting with an amount exceeding 60 c.c., had been under observation for more than two hours.

All the evaporated helium was collected into three portions, which gave densities of 2.04, 1.99, and 2.02. As a further test of purity a special comparative spectroscopic investigation was made with known mixtures of hydrogen with helium, and it proved that not more than 0.008 per cent. hydrogen was present. This high degree of purity is also confirmed by the easy working of all cocks, which would have been stopped by a very little frozen hydrogen, and also by the condition of the last remaining liquid. The thermometer was also controlled by a measurement of the boiling point of oxygen, which gave 89° K. instead of 90° K.

The properties found are as follows:—A boiling point of $4^{\circ}3$ K. on a constant volume helium ther-

mometer with a pressure of 1 atmosphere at about 20° K. Corrected to the absolute scale the best value would appear to be 4.5° K. The triple point, if it exists, is certainly below 1 cm., perhaps below 7 mm., at which, by corresponding states, the temperature would be about 3° K., and the liquid remains very mobile.

Liquid helium has a density of 0.15, which gives b a value of 0.00017, about twice that which has been assumed before from then known properties and used in calculations. From this, again, the critical pressure must be about 2 to 3 atmospheres, so that helium under 5000 would correspond with carbon dioxide under 100,000 atmospheres. At the boiling point the ratio of vapour to liquid density is 1:11, which indicates a critical temperature of not much more than 5° K., and a critical pressure of about 2.3 atmospheres. Lastly, the value of a will be about 0.00005, the smallest value known, but a most interesting confirmation of van der Waals's contention in 1873, that there must be some attraction between the molecules of all substances.

FRANCIS HYNDMAN.

THE ETIOLOGY OF TRYPANOSOMIASIS.

IN a communication to the Paris Academy of Sciences on February 24, some remarkable discoveries concerning the development of pathogenic trypanosomes in tsetse-flies are brought forward by M. E. Roubaud, member of the Mission Française d'Études de la Maladie du Sommeil. Experimenting with four species of pathogenic trypanosomes, namely, *Trypanosoma gambiense*, *T. dimorphon*, *T. brucei*, and *T. cazalboui*, and with *Glossina palpalis*, Roubaud found that immediately after the fly has fed on the blood of an infected animal, its proboscis contains blood in which the trypanosomes are moving actively. In a very short time, however, the trypanosomes attach themselves to the wall of the proboscis and undergo changes of structure, becoming Herpetomonas-like, with the kinetonucleus in front of the trophonucleus. The undulating membrane has disappeared, and the flagellum, as the organ of fixation, is greatly thickened, so as to resemble a small stalk to the body. These changes are complete in five minutes after ingestion of the blood. The attached parasites at first exhibit active movements of the body, but soon become quiescent; no phenomena of conjugation could be observed, either before or after these changes. But the parasites multiply actively in this situation, forming little tufts or colonies, so that at the end of one hour they have become excessively numerous; they are found attached to the internal face of the labrum, sometimes chiefly at the base of the proboscis, in other cases along its whole length as far as the point. When observed in the salivary fluid they appear immobile, but when treated with serum or with physiological salt-solution they vibrate rapidly and may become free, in which case they swim with the flagellum forward and the hinder part of the body rigid, thus differing greatly in appearance from the original trypanosome-form. The free parasites have a great power of attachment, and when under observation they may fix themselves firmly to the slide.

The author regards this development as a temporary culture or "culture d'attente" of the parasites. Both by observation and experiment he shows that the forms in the proboscis are not derived from trypanosomes regurgitated from the digestive tract of the tsetse. *T. brucei* was found to die out without multiplication in the intestine of *Glossina palpalis* in a short time. The culture in the proboscis was found

to persist beyond forty-eight hours in the case of *T. brucei*, and for five or six days in the case of the other three species of trypanosomes. Only about ten per cent., however, of the tsetses fed on infected animals developed a culture of the trypanosomes in the proboscis. On the other hand, the power of multiplying in the proboscis was found to be a specific relation between the trypanosomes and the tsetse.

These observations lack as yet the crucial test of an experimental infection by means of the proboscis-culture, but nevertheless they throw great light on the problem of the transmission of pathogenic trypanosomes. It has been shown by previous experimenters that the transmission is effected by the direct or mechanical method, and all attempts to prove experimentally an indirect or cyclical mode of transmission have given negative results. That being so, it was difficult to understand why the power of direct transmission should be possessed, apparently, by tsetse-flies alone, and not by other biting insects to an equal degree. Roubaud's observations show that the pathogenic trypanosomes have a quite specific power of adapting themselves to the salivary secretions of the tsetse, and thus explain the peculiar relation between these flies and the spread of diseases caused by trypanosomes in Africa. Moreover, a very important new line of investigation is indicated by the author's discoveries.

E. A. M.

NOTES.

ABOUT a year ago Sir William Ramsay and Mr. A. T. Cameron announced that they had observed the production of the alkaline metals and lithium in solutions of copper salts submitted to the action of the radium emanation, and concluded that in the presence of the emanation copper underwent a degradation into the elements potassium, sodium, and lithium. In the current number of the *Comptes rendus* of the Paris Academy of Sciences, Mmc. Curie and Mlle. Gleditsch give an account of the attempts they have made to repeat this experiment. They first point out the extreme difficulty of obtaining chemical products free from lithium. This metal was found in distilled water and in nearly all the reagents. If a reagent, free from lithium, is allowed to stand in a glass vessel, traces of this metal are found after some time. Even fused quartz is not a safe material, since both opaque and transparent quartz were found to contain notable amounts, the latter furnishing the larger proportion. The experiments had therefore to be carried out in such a manner that the solutions came in contact with platinum only; the water and the acids necessary for the experiment were re-distilled from platinum and preserved in platinum bottles, and after this treatment no lithium could be detected in the residue from 25 c.c. of the nitric acid, 25 c.c. of hydrofluoric acid, and 250 c.c. of water. The quantities of copper and radium emanation were about the same as those used in the original experiment. The salt residues obtained weighed 0.4 and 0.5 milligram, the control experiments giving 0.3 and 0.2 milligram. Spectroscopic examination of this residue showed it to consist of salts of sodium with a little potassium; the presence of lithium could not be proved. Direct experiments on known mixtures of sodium and lithium sulphates showed that the amount of lithium present in the residue, if any, must be less than 0.6×10^{-5} milligrams. In conclusion, the authors state that they have been unable to confirm the experiments of Messrs. Ramsay and Cameron. It is impossible to state that no trace of sodium or lithium is formed in this experiment, but they consider that the fact of the formation of these elements cannot be considered as established.